Alexithymia, rash impulsiveness, and reward sensitivity in relation to symptoms of exercise dependence in physically active young adults

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Alexithymia, Rash Impulsiveness, and Reward Sensitivity in Relation to Symptoms of Exercise Dependence in Physically Active Young Adults

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Abstract

Objective. Exercise dependence refers to excessive exercise accompanied by addiction-like symptoms such as craving, tolerance, withdrawal, impaired control, and disruption of life domains. The present study investigated whether personality traits linked to substance and behavioral addictions show similar associations with symptoms of exercise dependence. **Method.** Alexithymia and two forms of impulsivity, rash impulsiveness and reward sensitivity, were assessed in relation to exercise dependence symptoms in a sample of 99 physically active young adult men and women. **Results.** All three traits showed significant positive correlations with exercise dependence symptoms and were significant predictors of such symptoms in a hierarchical regression model. Alexithymia was the strongest predictor and fully mediated the contribution of rash impulsiveness according to bootstrapped mediation analysis. **Conclusions.** Findings suggest similar associations of addiction-linked traits with symptoms of exercise dependence and are discussed in terms of potential mechanisms.

Keywords: exercise psychology; sport psychology; personality; health; addiction

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The physical and psychological benefits of regular exercise are well-established (WHO, 2010), yet there can be negative effects such as acute or chronic injuries, especially when exercise becomes excessive. A minority of those who exercise regularly may become psychologically dependent on exercise and exhibit symptoms similar to addictions such as craving, impaired control, tolerance, withdrawal, engaging in the behavior despite negative consequences such as injuries, and interference with other life domains (Hausenblas & Symons Downs, 2002a). A review by Sussman et al. (2011a) concluded that the prevalence rate of exercise dependence in the general population is approximately 3%, though a prevalence of nearly 9% was reported in a sample of gym attendees (Manfredi & Gambarini, 2015). As a relatively new concept, exercise dependence has also been referred to as exercise addiction, obsessive exercise, compulsive exercise, exercise abuse, obligatory exercise and problematic practice of physical exercise (Egorov & Szabo, 2013).

Exercise dependence has been reported to show comorbidity with other compulsive behaviors, most commonly eating disorders; this has justified a distinction between "primary" and "secondary" exercise dependence with the latter defined by a reportedly reciprocal relationship with eating disorders and weight loss motivation (Cook & Hausenblas, 2008; Cunningham et al., 2016; Di Lodovico et al., 2018; Meyer et al., 2011). Irrespective of typology, negative psychological symptoms are common correlates of exercise dependence (Back et al., 2019; Costa et al., 2013; Grandi et al., 2011; Meyer et al., 2011; Weinstein et al., 2015). For example, Li et al. (2015) reported that compared to non-dependent students, those with exercise dependence reported higher levels of negative moods such as depression and anxiety, similar to those with substance or eating disorders (e.g., Harrison et al., 2010; Lyvers, Hinton et al., 2014; Thorberg et al., 2017). Also similar to other disorders characterized by compulsive behaviors are the disruptions to social life and personal relationships reported by those with exercise dependence, in this case due to an overriding

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commitment to exercise regimens. A unique aspect of exercise dependence is the increased risk of musculoskeletal injuries, as individuals who exercise compulsively may exercise to the point of injuring themselves and continue to exercise despite the injury (Freimuth et al., 2011; Lichtenstein et al., 2017).

The neurophysiological basis of exercise dependence may be similar to that of substance use disorders. According to Dietrich's (2006) transient hypofrontality hypothesis, exercise improves mood by temporarily inhibiting various brain regions including prefrontal cortex; such hypofrontality can also be induced by addictive drugs such as alcohol, cocaine and heroin (Lyvers, 2000). The mood-enhancing effects of exercise suggest a link to reward drive in exercise dependence, similar to substance addictions (e.g., Beck et al., 2009; Lyvers, Hinton et al., 2014). Freimuth et al. (2011) outlined how an individual may progress from healthy involvement in exercise to dependence. In Freimuth et al.'s interpretation, adopting an exercise regimen typically begins as a healthy activity without negative consequences. However, when the individual recognizes the psychological benefits of exercise such as mood elevation and stress reduction, they may start to organize their life around exercise, tend to exercise alone, and suffer negative consequences such as injuries or persistent muscle soreness. Eventually, addiction symptoms such as craving, tolerance and withdrawal may develop. Exercise dependence symptoms thus present at the extreme end of a continuum with normal exercise regimens. Though such hypotheses provide plausible explanations for the progression and maintenance of exercise dependence, they do not explain why some people who exercise regularly become dependent on exercise whereas most do not, similar to the question of why only a minority of substance users or gamblers become addicted (Egorov & Szabo, 2013).

Personality Traits as Risk Factors

Some personality traits have been invoked as potential risk factors for exercise

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dependence, including extraversion, narcissism, and neuroticism (Bircher et al., 2017; Cook et al., 2020; Costa & Oliva, 2012; Di Lodovico et al., 2018; Lichtenstein et al., 2014). Alexithymia and impulsivity are additional traits that have been widely linked to substance and behavioral addictions as risk factors (Cruise & Becerra, 2018; Kandri et al., 2014; Lyvers, Hinton et al., 2014; Mahapatra & Sharma, 2018; Marchetti et al., 2019; Rose & Segrist, 2012; Toneatto et al., 2009), hence the present study investigated their potential associations with symptoms of exercise dependence in a young adult sample.

Alexithymia is a multifaceted personality construct characterized by utilitarian and concrete cognition and difficulties with experiencing and describing feelings (Bagby et al., 2020). It has been regarded as a unique trait dimension that does not show significant overlap with other well-known personality constructs such as the Big Five (Wise et al., 1992). In Australia, high alexithymia as defined by established cut-off score on the Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994b) showed a prevalence of 46% in psychiatric samples versus 12% in community samples (McGillivray et al., 2016). Longitudinal research has indicated that alexithymia tends to be stable over time, showing little change from baseline testing to up to 11-years follow up (Hiirola et al., 2017; Salminen et al., 2006; Tolmunen et al., 2011). A large-scale twin study by Jorgensen et al. (2007) suggested relatively low heritability of alexithymia, thus subsequent research has suggested that high alexithymia may originate in adverse childhood experiences such as neglect, trauma, inadequate maternal bonding and insecure attachment (Lyvers et al., 2019; Thorberg et al., 2011a).

The reported prevalence of high alexithymia in substance abusing samples ranges from 30-50% (Cruise & Becerra, 2018; Lyvers, Hinton et al., 2014; Thorberg et al., 2009), commonly interpreted as reflecting use of substances for emotional self-regulation, which is deficient in alexithymia. For example, in young adults, alexithymia was positively associated

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with risky or problematic alcohol or cannabis use and with the use of such substances to cope with negative moods (Lyvers et al., 2018). Alexithymia has also been linked to behavioral addictions and other compulsive behaviors including compulsive buying (Rose & Segrist, 2012), internet addiction (Kandri et al., 2014; Lyvers et al., 2016; Mahapatra & Sharma, 2018), pathological gambling (Marchetti et al., 2019; Toneatto et al., 2009) and eating disorders (Marsero et al., 2011). However, relatively few studies have examined alexithymia in the context of exercise. A qualitative study of male swimmers by Allegre et al. (2007) suggested that expert swimmers were more alexithymic than amateur swimmers. Manfredi and Gambarini (2015) reported a positive relationship between scores on the TAS-20 and the Exercise Dependence Scale (EDS-21; Hausenblas & Symons Downs, 2002b) in an Italian sample of gym attendees; EDS-21 criteria identified that nearly 9% of the sample was exercise dependent. More recently, Van Landeghem et al. (2019) found that exercise dependence symptoms, as measured by the EDS-21, were positively associated with alexithymia as measured by the Bermond-Vorst Alexithymia Questionnaire (BVAQ; Vorst & Bermond, 2001) in an undergraduate student sample. The present study used the EDS-21 to measure exercise dependence symptoms in a sample of physically active young adults.

Like alexithymia, trait impulsivity has also been linked to alcohol abuse and dependence (Littlefield & Sher, 2010), eating disorders (Beck et al., 2009; Claes et al., 2002; Kane et al., 2004) and internet addiction (Dalbudak et al., 2013; Lyvers et al., 2016; Ryu et al., 2018). Impulsivity is a multifaceted construct that Dawe et al. (2004) suggested is best conceptualized in the context of substance abuse by a two-factor model, the 2-Component Approach to Reinforcing Substances (2-CARS) model (Gullo & Dawe, 2008; Gullo et al., 2010; Stautz et al., 2017), incorporating rash impulsiveness and reward drive. An individual with a high level of rash impulsiveness would tend to act without thinking, disregard risk and fail to consider the future consequences of their actions. Rash impulsiveness has a stronger

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genetic component than alexithymia (e.g., Anokhin et al., 2015), however both impulsivity (Littlefield & Sher, 2010; Spinella, 2004) and alexithymia (Chester et al., 2015; Kano & Fukudo, 2013; Lyvers, Makin et al., 2014) have been linked to generalized executive dysfunction and deficient prefrontal cortical activation during tasks that normally activate that brain region. Given the higher heritability of rash impulsiveness, one possibility is that high inherent levels of this trait may predispose to development of alexithymia in response to childhood neglect, trauma or inadequate parental bonding (Gullo & Dawe, 2008; Lyvers et al., 2019), perhaps accounting for the reported positive association between the two traits (Shishido et al., 2013). Dawe et al. suggested that rash impulsiveness can be measured by total scores on the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995), which includes items assessing motor, attentional, and non-planning impulsiveness as facets. As BIS-11 scores have shown positive relationships with symptoms of a variety of substance and behavioral addictions (Dalbudak et al., 2013; Lyvers, Hinton et al., 2014; Ryu et al., 2018), the BIS-11 was used as an index of rash impulsiveness in the present study of exercise dependence symptoms.

The other form of impulsivity relevant to addictions in the 2-CARS model, as proposed by Dawe et al. (2004), is sensitivity to reward (SR), which the authors suggested can be measured by the SR subscale of the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001). Like rash impulsiveness, SR or reward-driven impulsivity has been linked to a variety of compulsive behaviors as a likely risk factor (e.g., Beck et al., 2009; Lyvers, Hinton et al., 2014). The SPSRQ was thus used in the present study to measure SR in relation to exercise dependence symptoms, and was expected to be positively related to such symptoms given the well-known mood enhancing effects of exercise.

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Considering the support for the 2-CARS model of impulsivity in relation to other excessive behaviors, the present study sought to extend this paradigm to symptoms of exercise dependence. For example, those at risk of exercise dependence may be particularly sensitive to the positive reward-based incentives of exercise, whether this be winning in competition, achievement of mastery, improvement in appearance, or direct positive mood effects of exercise. Rash impulsiveness may be manifested by continuing to exercise despite signs of over-exertion or impending injury (Freimuth et al., 2011; Lichtenstein et al., 2017). The present study therefore investigated the 2-CARS model of impulsivity proposed by Dawe et al. (2004) in relation to the EDS-21 measure of exercise dependence symptoms to assess whether either or both forms of impulsivity may be risk factors for exercise dependence as has been reported for other forms of excessive behavior. The prevalence of full exercise dependence by EDS-21 criteria was anticipated to be low in the current non-clinical sample of physically active young adults, who were not recruited from gyms or other venues likely to be frequented by exercise dependent individuals (Manfredi & Gamberini, 2015). However, addictive behaviors are recognized as existing at the extreme end of a continuum (APA, 2013; SAMHSA, 2016), such that lower levels of symptoms can progress to higher levels in susceptible individuals; thus relationships of the traits of interest with exercise dependence symptoms were anticipated in the present sample.

Specifically, scores on the measures of alexithymia, rash impulsivity and SR were expected to be significantly positively correlated with EDS-21 scores, and were anticipated to be significant predictors in a hierarchical regression model. Sex was controlled as a covariate given that some studies have reported sex differences on the traits of interest, particularly alexithymia (e.g., Hiirola et al., 2017; Levant et al., 2009; Salminen et al., 2006), and that so-called primary exercise dependence, which is not associated with a comorbid eating disorder, has been reported to be more common in males (Costa et al., 2013; Cunningham et al., 2016).

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The contributions of alexithymia and rash impulsiveness were expected to show some degree of overlap in accounting for variance in exercise dependence symptoms, based on previous evidence of a positive association of rash impulsiveness with alexithymia in the context of substance use (Lyvers et al., 2013; Shishido et al., 2013) as well as the evidence cited earlier suggesting that high levels of either trait reflect generalized executive/prefrontal dysfunction. The degree of independence of alexithymia and rash impulsiveness in relation to symptoms of exercise dependence was assessed by regression followed by a planned bootstrapped mediation analysis.

Method

Participants

The initial sample consisted of 119 young adults recruited from two university campuses in southeast Queensland, Australia, and from other states via Qualtrics Panels. Due to the covid-19 pandemic and resulting low student presence at the two universities at the time of the study, most participants were recruited online via Qualtrics Panels (n = 84); they were contacted via email by the recruitment team at Qualtrics and were provided points-based incentives. Participants from one university (n = 23) were recruited through an online undergraduate psychology student participation noticeboard and were offered course credit as an incentive. At the other university, participants (n = 12) were recruited via campus-wide email and were not offered any incentive. The advertisement for the study asked for participants who were 18-30 years old and who regularly (i.e., at least weekly) engage in exercise or sport, with no history of traumatic brain injury and no current use of medication for a psychiatric or neurological disorder. After excluding cases that did not meet one or more inclusion criteria, the final sample of 99 participants aged 18 to 30 years (M = 24.53, SD = 3.56) was obtained, including 56 females and 43 males. G*power 3.1.9.7 indicated that for a small effect size (.20), power of .90, alpha of .05, and five predictors in multiple regression, a

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minimum sample size of 89 was required; the final sample of 99 was thus adequate for present purposes.

Scoring protocols for the EDS-21 index of exercise dependence symptoms (described below) indicated a high rate of exercise dependence symptoms in the sample, such that 71% were classified as "symptomatic," though only a further 2% could be classified as fully exercise dependent (which was close to the estimated prevalence in the general population; Sussman et al., 2011a). Nearly all participants (92%) reported exercising at least 2-3 times per week; 84% reported that their primary exercise consisted of fitness-oriented activities, with the remainder reporting engaging in either team sports on recreational non-team sports as their primary exercise.

Materials

Demographics Questionnaire. This questionnaire requested information from the participants regarding their age, sex, education, study status, exercise habits and any history of brain injury or psychiatric/neurological conditions (for screening purposes).

Toronto Alexithymia Scale 20 (TAS-20; Bagby et al., 1994a). The TAS-20 is a self-report questionnaire designed to measure alexithymia via items assessing difficulty identifying feelings (DIF), difficulty describing feelings (DDF), and externally oriented thinking (EOT). It is the most widely used measure of alexithymia (Bagby et al., 2020). The scale consists of 20 items (e.g., "I am often puzzled by sensations in my body"), five of which are reverse scored (e.g., "Being in touch with emotions is essential"); response options are anchored on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Item responses are summed to yield a total score, where higher scores indicate higher alexithymia. There are cutoff scores for high alexithymia (61+) and low to no alexithymia (< 52), with scores in between considered borderline. The present study used the total score as

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recommended by the authors of the TAS-20 (see Sekely et al., 2018). Internal consistency reliability was acceptable in the current sample (α = .83).

Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995). The BIS-11 is a self-report measure of rash impulsiveness (Dawe et al., 2004) via items assessing attentional impulsiveness (inability to focus attention or concentrate), motor impulsiveness (acting without thinking), and non-planning impulsiveness (lack of future time orientation). The scale consists of 30 items (e.g., "I say things without thinking"), 11 of which are reverse scored (e.g., "I plan tasks carefully"); response options are scored on a five-point Likert scale from 1 (rarely/never) to 5 (almost always/always). Total scores are obtained by summing item responses, with a higher total score indicating a higher level of rash impulsiveness (Dawe et al., 2004). Internal consistency reliability was acceptable for the current sample (α = .83) and was the same as previously reported by Stanford et al. (2009).

Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001). The SPSRQ is a self-report measure designed to assess everyday influences of the Behavioral Approach and Behavioral Inhibition systems on an individual's behavior, based on Gray's (1987) Reinforcement Sensitivity Theory. There are two corresponding subscales, Sensitivity to Reward (SR) and Sensitivity to Punishment (SP). These subscales consist of 24 items each, with response options of "yes" or "no." Even numbered items tap SR; e.g., "Do you like displaying your physical abilities even though this may involve danger?" Odd numbered items tap SP; e.g., "Whenever possible, do you avoid demonstrating your skills for fear of being embarrassed?" Subscale scoring is completed by adding all "yes" responses, with a higher score indicating higher SR or SP. In the current sample, internal consistency reliability was acceptable for both SP (α = .82) and SR (α = .77).

Exercise Dependence Scale Revised (EDS-21; Hausenblas & Symons Downs, 2002b). The EDS-21 is a 21 item self-report questionnaire assessing symptoms of exercise

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dependence based on the DSM-IV (APA, 2000) criteria for substance dependence. Each of the seven criteria indicative of exercise dependence (tolerance, withdrawal, intention effects, lack of control, time, reduction in other activities, and continuance) is assessed by three items. Response options are anchored on a six-point Likert scale, with options ranging from 1 (never) to 6 (always). Examples of items include "I exercise to avoid feeling irritable" and "I exercise when injured." Item responses can be summed to provide an overall score where higher scores indicate higher levels of exercise dependence symptoms. Criteria are also provided for classification of respondents as non-dependent, symptomatic, or dependent. In the current sample internal consistency reliability of the total EDS-21 was high ($\alpha = .96$).

Procedure

Ethics approval was obtained from the Bond University Human Research Ethics Committee (approval number TS02912) prior to data collection. The internet survey hosting service Qualtrics was used to post the measures online. On clicking the link provided, the first page presented an explanatory statement which provided contact details of the researchers, described the general purpose of the study in lay terms, and explained that all information collected was anonymous. Participants were asked to tick a box to provide informed consent. Participants then completed the demographics questionnaire, after which the other questionnaires were presented in uniquely randomized orders for each participant. Each question required a response, such that participants could not continue to the next question until they had responded to the previous one. Completion of all measures took approximately 30 minutes.

Results

Data are available on request and were collected via Qualtrics and imported to an IBM SPSS Statistics (Version 26.0) datafile for analysis via JASP 0.14.1. Data screening indicated that for the variables of interest there were no missing values, no univariate or multivariate

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outliers, and no evidence of multicollinearity; skewness and kurtosis were within the acceptable range (Tabachnik & Fidell, 2014). Comparison of males and females on all variables of interest using multivariate analysis of variance indicated no significant sex differences; however, TAS-20 alexithymia scores approached significance. Males scored nonsignificantly higher on the TAS-20 (M = 58.35, SD = 10.83) than females (M = 54.21, SD = 11.81), p = .08, hence sex was included as a covariate in regression and mediation analyses. No other measures approached significance.

Correlational Analysis

Descriptive statistics and Pearson correlations for continuous variables are shown in Table 1. As predicted, significant positive correlations were obtained between participants' EDS-21 and TAS-20, BIS-11, and SPSRQ-SR scores. SPSRQ-SP scores showed small to moderate positive correlations with BIS-11 and SR, respectively, but were not correlated with EDS-21; nevertheless SP was included in subsequent analyses given its correlations with the other predictors. Age was not correlated with any of the variables of interest and was thus not entered as a covariate in regression.

Regression on Exercise Dependence Symptoms

Hierarchical regression was conducted on EDS-21 scores. Sex was entered at step 1 as a covariate for reasons described earlier; the impulsivity-linked trait measures BIS-11 and SR, as well as SP, were entered at step 2, followed by the TAS-20 alexithymia measure at step 3. At step 1, sex accounted for only 2% of variance and was not significant, $F(1, 97) = 1.77$, p = .19. At step 2, SR, SP, and BIS-11 explained 15% of additional variance, which was significant, $\Delta F(3, 94) = 5.74$, p = .001; as expected, SR and BIS-11 were significant predictors (see Table 2). At step 3, TAS-20 scores explained 16% of additional variance, which was significant, $\Delta F(1, 93) = 21.78$, $p < .001$; TAS-20 and SR were significant predictors, whereas

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BIS-11 was no longer significant. The final model was significant and accounted for 33% of variance in EDS-21 scores, $F(5, 93) = 9.06$, $p < .001$.

Mediation Analysis

As anticipated based on previously cited evidence of high rash impulsiveness associated with alexithymia in the context of substance use, the contribution of BIS-11 scores became nonsignificant when TAS-20 scores were entered into the regression model, suggesting that the relationship between BIS-11 and EDS-21 scores was mediated by alexithymia. The mediation hypothesis was tested using bootstrapping with 1000 bias-corrected replications, controlling for sex, SR and SP as covariates. The 95% confidence interval for the indirect effect of rash impulsiveness through alexithymia did not include zero (.07, .42). The model as depicted in Figure 1 indicated full mediation by alexithymia, $p < .001$. By contrast, reversing the mediation model, with rash impulsiveness as the presumed mediator between alexithymia and exercise dependence symptoms while controlling for sex, SR and SP, did not show a significant indirect effect ($p = .41$).

Discussion

All predictions were supported in the present sample of physically active male and female young adults. The two forms of impulsivity specified by the 2-CARS model of Dawe et al. (2004) as inherent risk factors for addictions, i.e., reward sensitivity and rash impulsiveness, were both positively correlated with scores on the EDS-21 index of exercise dependence symptoms and predicted EDS-21 scores in a regression model. However, entry of alexithymia into the model explained more variance in exercise dependence symptoms and fully mediated the contribution of rash impulsiveness. Interestingly, there was no reverse mediation; rash impulsiveness did not mediate the association of alexithymia with exercise dependence symptoms. Alexithymia was thus the trait most strongly associated with exercise dependence symptoms in the present sample. The findings add to the traits implicated as

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potential risk factors for exercise dependence, and reinforce previous reports of a positive relationship between alexithymia and exercise dependence symptoms in gym attendees (Manfredi & Gambarini, 2015) and undergraduate students (Van Landeghem et al., 2019).

As discussed earlier, both alexithymia and impulsivity have been identified as traits linked to a variety of addictions and other excessive behaviors. However, there has been comparatively little research assessing alexithymia or impulsivity in relation to exercise dependence symptoms, a gap the present study sought to address. Using Dawe et al.'s (2004) 2-CARS paradigm of two forms of impulsivity relevant to addictions, present results suggested largely independent contributions of alexithymia and reward sensitivity to exercise dependence symptoms, whereas the contribution of rash impulsiveness was indirect through its association with alexithymia. The role of reward sensitivity would presumably reflect the numerous benefits of exercise, including positive mood changes and stress relief. Indeed, engaging in exercise is often recommended as a means to aid recovery from substance use disorders, with some empirical support (e.g., Smith & Lynch, 2012). However, alexithymia was by far the strongest predictor of exercise dependence symptoms in the present sample, which raises the question as to why.

The links between alexithymia and various excessive behaviors have often been attributed to self-medication of the negative moods commonly associated with alexithymia such as depression and anxiety (Ghalehban & Besharat, 2011; Lyvers, Hinton et al., 2014; Lyvers et al., 2018, 2020; Thorberg et al., 2009, 2011b, 2017). A different interpretation was offered by Brewer et al. (2016), who suggested that deficient interoceptive awareness accounts for excessive substance use or eating disorders in alexithymia. Present results are consistent with both interpretations. The ability of exercise to relieve stress and regulate mood is well known, hence exercise can be used as a means of coping with negative affect (Dietrich, 2006; Egorov & Szabo, 2013; Freimuth et al., 2011; Sussman et al., 2011b), which as noted

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earlier is prevalent in high alexithymia (Thorberg et al., 2009). In addition, deficient interoception may impair recognition of internal cues of over-exertion or impending bodily injury during exercise, with the result that exercise continues despite negative health consequences. The insecure attachment style and dissatisfaction with personal relationships reported by those with high alexithymia (Besharat et al., 2014; Humphreys et al., 2009; Thorberg et al., 2011b) may also encourage solo activities such as exercise at the expense of social interactions and responsibilities. Future work could evaluate the potential mechanisms of the relationship between alexithymia and exercise dependence symptoms, e.g., by including measures of negative mood, interoceptive awareness and attachment style as potential mediators.

The present study had several limitations. The cross-sectional design did not allow interpretation of relationships among variables in terms of causation, hence longitudinal studies are needed. On the other hand, as noted earlier the traits assessed in the present study appear to be relatively stable over time and likely have an early onset, although impulsivity appears to have a stronger genetic basis than alexithymia. Both impulsivity and alexithymia have been interpreted as different manifestations of generalized executive dysfunction that may predispose to addictions and other excessive behaviors (Lyvers, Hinton et al., 2014; Thorberg et al., 2017). The use of a non-clinical sample of young adults with a low rate of exercise dependence (2%), based on EDS-21 criteria, was also a potential limitation though there was a high rate of "symptomatic" participants (71%) in the sample. The present approach was premised on the currently accepted notion that addictive behaviors present on a continuum of symptoms with behavior that is not excessive (APA, 2013; SAMHSA, 2016), and that risk factors may lead susceptible individuals to progress to addiction over time; nevertheless, the present findings cannot be generalized to clinical samples.

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A further issue concerns the reported comorbidity of exercise dependence with eating disorders, which has led to a distinction between primary and secondary exercise dependence; the latter type is defined by this comorbidity and is more common in females as discussed earlier. In the present sample there were no sex differences on any of the measures of interest, though there was a trend for higher alexithymia in males, and in any case the potential influence of sex differences was controlled by covariate analysis. However, there was no measure of disordered eating. Future research may consider comparing primary and secondary exercise dependence in relation to alexithymia, though given the known association of alexithymia with eating disorders (Marsero et al., 2011), the results might be anticipated to be similar for both types of exercise dependence.

The prevalence of high alexithymia in the current sample (37%), as defined by established TAS-20 cutoff score (Bagby et al., 1994b), fell between the estimated Australian prevalence of 12% in non-clinical samples and 46% in clinical samples (McGillivray et al., 2016). The prevalence in the present sample was thus surprisingly high, although a similar prevalence was reported in a recent study of frequent Facebook users in Australia (38% prevalence; Lyvers et al., 2020). In the latter study this was attributed to online recruitment of participants, based on evidence that individuals with high alexithymia spend more time on the internet and are thus more likely to be represented in samples recruited online. In the present study, most participants were similarly recruited online due to the covid-19 pandemic, which may limit generalizability of the findings. Another unusual feature of the current sample was the moderate positive correlation between SR and SP. This was surprising given that SR and SP are theorised to reflect the influences of distinct brain systems in Gray's (1987) BIS/BAS theory (Behavioral Inhibition or amygdala system and Behavioral Approach or dopaminergic reward system, respectively), which the SPSRQ scales are designed to assess. In any case, this unexpected relationship was controlled for in the regression and mediation analyses.

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Despite the aforementioned limitations, the present findings reinforce the notion that excessive exercise shares features in common with other excessive behaviors, in this case traits presumed to be risk factors for substance and behavioral addictions. Future research should focus on elucidating the complex relationships between trait factors as potential contributors to risk of exercise dependence, so that the roles of inherent risk factors are better understood and can be targeted effectively when needed.

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Table 1

Descriptive Statistics and Intercorrelations Among Variables (N = 99)

Variable	*M (SD)*	1	2	3	4	5	6
1. Age	24.53 (3.56)	-					
2. Alexithymia	56.01 (11.53)	.05	-				
3. Rash Impulsiveness	70.23 (11.24)	.09	.47***	-			
4. Reward Sensitivity	12.04 (4.98)	-.03	.27**	.27**	-		
5. Punishment Sensitivity	13.92 (5.16)	-.08	.17	.29**	.50***	-	
6. Exercise Dependence	54.93 (19.27)	-.02	.53***	.31**	.28**	.03	-

$p < .05$. **$p < .01$. ***$p < .001$.

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Table 2

Hierarchical Multiple Regression on Exercise Dependence Symptoms with sex and scores on rash impulsiveness (BIS-11), sensitivity to reward (SR), sensitivity to punishment (SP), and alexithymia (TAS-20) as predictors.

Predictor	ΔR^2	β	*B*	*SE B*	95% CI for *B*
Step 1	.02				
Sex		.13	5.18	3.89	[-2.54, 12.91]
Step 2	.15***				
Sex		.09	3.50	3.76	[-3.98, 10.97]
BIS-11		.29**	.50	.17	[.16, .84]
SR		.27*	1.05	.44	[.18, 1.92]
SP		-.18	-.66	.42	[-1.49, .17]
Step 3	.33***				
Sex		.01	.18	3.48	[-6.73, 7.09]
BIS-11		.08	.14	.17	[-.20, .48]
SR		.22*	.84	.40	[.05, 1.63]
SP		-.18	-.67	.38	[-1.42, .08]
TAS-20		.47***	.78	.17	[.45, 1.11]

Note. SE B = standard error of unstandardized coefficient; CI = confidence interval.

* $p < .05$. ** $p < .01$. *** $p < .001$.

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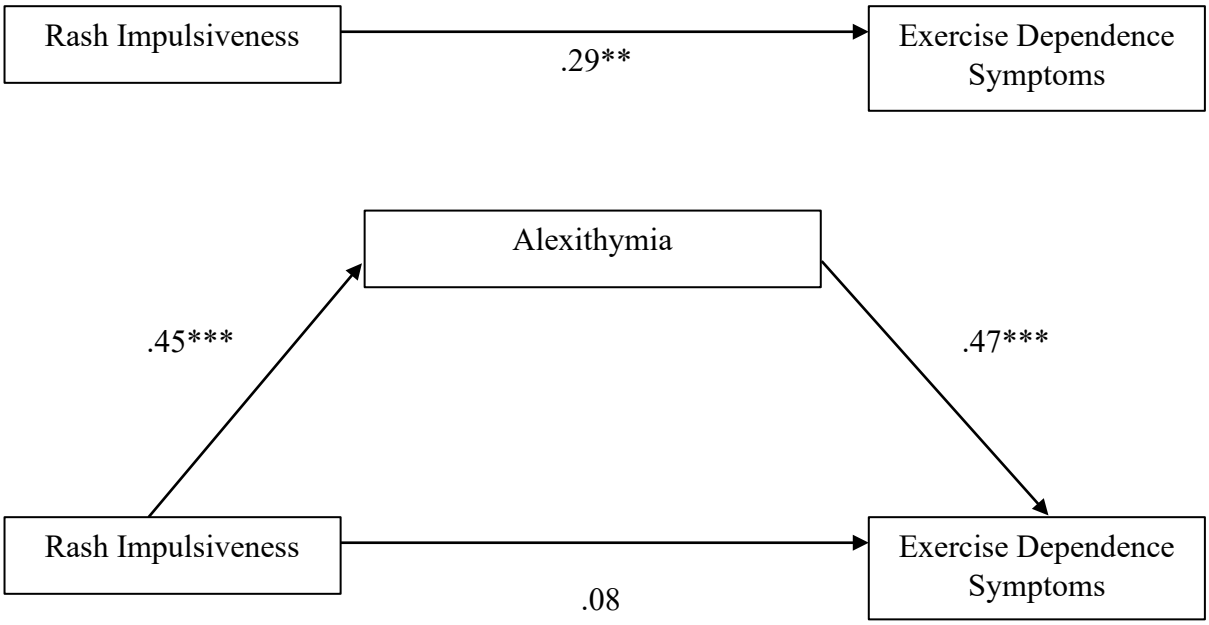
Figure 1. Unmediated and mediated models of the association between rash impulsivity and exercise dependence: support for full mediation by alexithymia. Standardised beta coefficients are shown for all paths. Sex, SR, and SP were controlled as covariates.



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